NASA-CR-200766

A Low Cost Simulation System to Demonstrate Pilot Induced Oscillation Phenomenon

Second Annual Performance Report
(according to NASA Handbook 5800.1C paragraph 1260.402)

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Covered Period: April 1, 1995 to March 31, 1996

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Research Grant No. NAG 2 - 4006

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SUMMARY OF PERFORMANCE

The first phase of the project has been the installation of a computer workstation based flight simulation facility with graphics. The software on the workstation facility must have such sensitivities and precision that in addition to the general aspects of flight dynamics, the pilot induced oscillations may also be simulated and analyzed with reasonable accuracy. The second phase of the project is to use the facility to conduct research on pilot induced oscillation phenomena.

The simulation software, which represents the dynamics of flight of an F-15 fighter airplane, has been installed by NASA-Dryden Flight Research Center on an SGI 4D/420 IRIS workstation. This workstation is located in the Flight Vehicle Design Lab of Aerospace Science Engineering Department at Tuskegee University on loan from NASA-Dryden Research Center.The two central processing units on IRIS workstation are not enough when the simulation is operated with a joystick instead of a mouse. The graphics program of the simulation software has been moved to the central processing unit of SGI INDIGO2, which is another available workstation for the project. The flight simulation is thus operated by a joystick and it occupies three processing units, two units on IRIS and one on INDIGO2. Both workstations are equipped with uninterrupted power supply and both of them are connected to ethernet.

At Tuskegee University, the Flight Vehicle Design Lab now has F-15 simulation software with graphics on a set of SGI workstations, essentially operated by a joystick. This facility is a low cost computer based simulation facility, which is suitable for the study and demonstration of pilot induced oscillations. Thus a milestone of the proposed project has been reached. A demonstration,study, and analysis of pilot induced oscillations on the available computer based simulation facility are now being designed with a plan to obtain substantial research results before August 15, 1996.

This project has motivated ten undergraduate students to study and learn flight simulation. One of the students, Jason Williams, has acquired a working knowledge of the Unix Operating System and skill to operate the F-15 simulation. The addition of two SGI workstations and their use in the Aerospace Engineering Department has been an upgrade in computer facility that has a pleasant influence on students' enthusiasm.

Some references have been identified as the useful ones to design pilot induced oscillation experiments. Eight licensed pilots of NAI(an airmen club) have offered their voluntary help to operate the experimental flights on simulation for the research.

PROJECT FEATURES

The present F-15 simulation software is essentially one of the software systems that are developed and supported by NASA Dryden Flight Research Center. Norlin (ref 1) has provided a description of their software design, model development, and simulation capabilities. The F-15 simulation is coded with a FORTRAN shell and C support routines and it operates on UNIX-based platform. On Tuskegee University campus, the F-15 real time simulation with pilot in the loop has a joystick for the pilot instead of a mouse. To run the simulation without pilot in the loop, a script file is generated to determine a flight mission which helps to perform repeatable flight tests. The integration scheme in the simulation has been optimized for real time operation and it is briefly described in reference 1.

Roskam (ref 2) provides an analysis of airplane plus pilot as a closed loop control system. The factors that constitute the pilot transfer function are the pilot gain, the pilot reaction time delay, and the pilot equalization characteristic. According to Roskam, the pilot reaction time delay is 100 ms for the test pilots and 120 to 200 ms for other pilots.

Preliminary studies have been undertaken with the volunteer pilots and their suggestions are being considered in the experimental program of the present simulation project.The experimental program will focus on the deviations in speed, altitude, and heading when a pilot in the loop is required to maintain straight level flight. Experiments will be performed without introducing any additional delay to the existing and the natural delays of the closed loop system. Experiments will also be performed after introducing additional delays of up to 200 ms in the closed loop system. Absence and presence of gust will be allowed to obtain different sets of data. Voluntary help of eight certified pilots will be used to run the experiments. Upon completion of the above straight level flight experiments, additional studies, described below, would be considered.

A flight experiment would be attempted to enable estimation of transfer functions of pitch control system and its feedback sensor. Then, from the transfer function of pilot in the loop system, the pilot transfer function would be estimated.

Rogers (ref 3) reports that aircraft in the Airbus family are designed to have flight path stability as opposed to the traditional static stability. Flight path stability results in the flight control system's maintaining the aircraft in a constant flight path. For example, a pilot commands a 3-degree final approach flight path, and the flight control system works to maintain that path, compensating for changes in air speed or pitch perturbations due to turbulence. In the present project, PIO experiments on a 3 to 5 degree final approach flight path would be considered.

In the present simulation project, attempts would be made to predict and verify longitudinal PIO by using the six step technique proposed by Hess and Kalteis (ref 4).

CHRONOLOGY OF PROGRESS AND LESSONS LEARNED

Before April 1995
(Prior to the period covered by this report)

A Silicon Graphics INDIGO2 workstation with single CPU, with 64 MB memory including upgrade, and with C, C++, and FORTRAN 77 compilers was acquired under the grant. It was named silicon and it got connected to Ethernet.

April to June 1995

An SGI 4D/420 IRIS workstation with F-15 Simulation software and with C and FORTRAN compilers arrived the Flight Vehicles Lab at Tuskegee University on loan from NASA Dryden. For few days the workstation could not get started. Active email communication between Tuskegee University and NASA Dryden resulted in identifying the fault and getting the workstation started. Permission was obtained from Silicon Graphics for using their Simulation Demo Graphics Source Code.

Mr. Ken Norlin and Mr. Dante Jackson from NASA Dryden visited the Tuskegee Campus. They ascertained proper installation of F_15 simulation on IRIS. They connected IRIS to ethernet with csdecl as its name. They provided brief training to the PI and to Jason Williams (student assistant)on the use of software. They conducted meetings with the PI and Dr. Amnon Katz of the University of Alabama (consultant on the project) to plan the experiments and to consider providing additional features to the software. With their help, the code was modified to obtain 200 ms or smaller delay between pilot's input and screen response.

July to December 1995:

For sometime the IRIS apparently lost some of its subroutines. The email communication between NASA and Tuskegee helped resolve the problem which turned out to be a loose wire connection. All the software was back and working. The project was scheduled to conclude on Aug. 31, 1995.A no cost extension was obtained on the project until Feb. 29, 1996.

A search was conducted to find a suitable joystick or other alternatives. A joystick, called FlyBox, from BG Systems, Inc. of Palo Alto, California, was found as the suitable one for the SGI flight simulation demos. The joystick and its software were purchased. With the help from the BG Systems the joystick was installed to operate the SGI demos.The guidance in the joystick manual was not adequate to install it to operate the F-15 simulation.

January to March 1996:

The principal achievement during this period has been the integration of joystick (FlyBox) with the F-15 simulation. This achievement has been made by the expert and dedicated help from Ken Norlin of NASA, generous voluntary expert help from Dr. C.L.Chen, a Computer Science Professor at Tuskegee, and Jason, the student worker on the project.

Now, we have a low cost simulation system to represent the flight dynamics of F-15 airplane. Pitch, roll, and yaw are obtained from the movements of the joystick, throttles on the two engines are obtained by two smaller sticks. The software including graphics takes up three processors on two SGI workstations, IRIS and INDIGO2

The very recent status, however, is that we are not able to run the complete simulation program. We are very hopeful to overcome the problem soon by providing a 10 base-T hub for ethernet connections and by improved temperature and humidity conditions in the laboratory.

Lessons Learned That Were Not Anticipated In the Proposal:

The SGI INDIGO2 was selected at the time of proposal with a belief that it would be capable of supporting the F-15 simulation software. It turned out that the software required a two CPU workstation. Fortunately, NASA Dryden had a two CPU workstation available for being loaned to Tuskegee.

It was noted that the mouse control to operate the flight simulation was too granular. Hence, a joystick had to be identified, purchased, and integrated with the system.

While working on the software to integrate the joystick, it was realized that IRIS workstation alone could not support the joystick to replace the mouse. Hence additional modifications in software and integration of INDIGO2 workstation with IRIS were required.

THE PERSONNEL

At present, two undergraduate students: Jason Williams and Yusef Johnson are working on the project. The Principal Investigator (PI) has the continued expert and kind help from Dr. Amnon Katz of the University of Alabama. Dr. Katz is the consultant on the project. The NASA Technical Officer, Mr. Larry Schilling maintained email communications with the PI to ascertain availability of NASA's managerial and technical help on the project. Mr. Ken Norlin, the Simulation Engineer of NASA, always responded to the challenging needs on software modifications. The PI is also grateful to Dr. C.L.Chen, Dr. Vascar Harris, Mr. Abraham George, and Mr. Ernest Kashiri of Tuskegee University for their generous voluntary help through their respective expertise.

REFERENCES

1. Norlin,Ken A."Flight Simulation Software at NASA Dryden Flight Research Center", Proc. AIAA Flight Simulation Tech.Conf., Baltimore, Aug.7-10,1995, pages 213-230.

2. Roskam,Jan,"Airplane Flight Dynamics and Automatic Flight Controls",DAR Corporation,1995,(see chap.10,pages 763-777)

3. Rogers, Ronald J."Airbus A319 Flight Evaluation", Air Line Pilot, March 1996, pages 30-33.

4. Hess,R.A. and Kalteis,R.M."Techniques for Predicting Longitudinal Pilot Induced Oscillations", Journal of Guidance, Control, and Dynamics,vol 14,n 1,Jan-Feb 1991, pages 198-204.

ABSTRACTS OF REFERENCES

1. Norlin,1995: The NASA Dryden Flight Research Center has developed a versatile simulation software package that is applicable to a broad range of fixed wing aircraft. The paper discusses the features of the simulation software design and some basic model development techniques, and key capabilities that have been included in the simulation.

2. Roskam,1996: The reader is introduced to a mathematical model for human pilots so that closed loop control theory can be used to analyze the performance of airplane plus pilot in the loop combinations. Applications to pilots controlling bank angle and pitch attitude angle are presented.

3. Rogers,1996: The author has provided a report of the test flight of A319. The test flight was conducted by the author himself as the pilot. He has highlighted flight path stability as opposed to static stability.

4. Hess and Kalteis,1991: A technique for predicting the susceptibility of an aircraft to longitudinal pilot induced oscillations is proposed. The technique employs the optimum control model (OCM) of the human pilot formulated for pitch attitude command tracking tasks. The criterion is based on the pilot/vehicle open loop transfer function as predicted by the OCM.